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Developmental Coordination Disorder: current issues

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The concept of a specific disorder of motor function has been recognized for at least a century, with a gradual increase in awareness of this condition among health professionals and researchers developing over the past 30 years or so. First recognized in DSM-III-R (American Psychiatric Association 1987) as clumsy child syndrome, a number of labels have been applied to the disorder, including dyspraxia (Denckla 1984) and Specific Developmental Disorder of Motor Function (World Health Organization 1992). At present, however, common international approval has been expressed in favour of the term Developmental Coordination Disorder (DCD; Henderson & Henderson 2002; Sugden & Chambers 2005), the label assigned to the disorder in DSM-IV (American Psychiatric Association 1994, 2000). This idiopathic disorder is diagnosed in children who, for no medical reason, fail to acquire adequate motor skills. Typically, motor milestones are generally achieved rather late, while core aspects of this disorder can include difficulties in manual dexterity, ball skills and/or balance. Such marked impairment has a significant, negative impact on activities of daily living, such as dressing, eating, riding a bicycle, and/or on academic achievements, primarily as a result of poor handwriting skills (Barnett & Henderson 2005). DCD is not a trivial disorder as it affects around 5% of school-aged children, with a prevalence of boys over girls (3:1). Its onset is apparent in the early years, but usually it is not diagnosed formally before the age of 5 years. It has a varying, but significant, impact throughout the lifespan, and its symptoms are consistent across culture, race, socio-economic status and gender. Although the long-term prognosis of individuals with DCD is uncertain, adolescence and adulthood is characterized by persistent motor difficulties, in addition to social problems as well as medical and psychiatric consequences (Cousins & Smyth 2005).

In the past 30 years, diagnosis of this condition, development of assessment tools and research into the disorder has evolved. While much remains to be done to increase awareness, further strides are being made. This is particularly apparent when considering the level of attendance at international conferences on DCD, the latest of which triggered the papers published in this special issue. The Sixth International Conference on Developmental Coordination Disorder (DCD-VI), organized by Drs Stefania Zoia and Aldo Scabar (Institute of Child Health, IRCCS Burlo Garofolo, Trieste) and held in Trieste, Italy, saw 180 delegates from around the world attend a 4-day conference. The programme was very full and stimulating, with studies on research methods, postural control, sensorimotor control, handwriting, co-occurrence with other developmental disorders and intervention being presented in both oral and poster formats.

A further testimony to the quantity and quality of work on DCD comes from the number of papers that were submitted for consideration in this special issue. We were unable to include all of these for space reasons. Look out for other papers on DCD in subsequent issues of *Child: care, health and development*.

This special issue, *Developmental Coordination Disorder: current issues*, contains 11 papers, falling

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into four of the main themes of the DCD-VI conference: assessment, approaches to research, sensorimotor control and co-occurrence with other developmental disorders.

Assessment

Inter- and intra-individual variability within DCD is well documented and might interfere with the development of appropriate screening tools. In early infancy, proper identification of signs and symptoms is hampered by the lack of reliable tests and baseline data to the point that when motor difficulties are persistent, parents seem to be the ones who readily pick up the problems (Wilson & McKenzie 1998; Jongmans 2005). Standardized measures of movement skills are more readily available for children of school age. In recent years, a number of researchers have developed measures to aid with the identification of young children with DCD. One such attempt is documented in the first paper of this special issue. Here, Rosenblum (2006) describes the initial phases of the development of a reliable and valid screening tool, the Children's Activity Scales (ChAS). This scale uses a checklist approach, as opposed to the more conventional assessment of performance *in situ*. It comprises a parent (ChAS-P) and teacher (ChAS-T) checklist suitable for use with children aged 4–8 years at risk for DCD. A particular strength of this measure is that it has been developed to provide information about children's ability to function within the context of their natural environment. Items relate to gross and fine motor skill, organization in space and time during the performance of activities of daily living, mobility, ball skills, play activities, common school and preschool activities. Early reliability and validity data on the scale are encouraging.

Approaches to research

Specific theoretical approaches that make clear predictions between behavioural, cognitive and biological levels of understanding of neurodevelopmental disorders have been invaluable in understanding a range of disorders such as autism spectrum disorder and dyslexia (Morton 2004). In terms of DCD, we know rather little about its cognitive and biological basis, and specific theories of the disorder are (relatively) few and far between. The work of Williams and colleagues (2006) presents one such account, the *internal modelling deficit* (IMD) theory, and tests it using a mental rotation paradigm. While not conclusive, the study lends some support to the IMD hypothesis. Results suggest that many children with DCD have difficulties mentally simulating a movement. This problem may reflect a reduced ability to represent the external workspace in body-centred coordinates or, indeed, to develop an accurate feedforward model of an action. Intervention studies using motor imagery have been designed successfully for children with DCD (e.g. Wilson et al., 2002). Future work will determine how generalisable these training effects are.

One interesting question arising from the study of Williams and colleagues (2006) as well as from other studies concerns the issue of subgroups of DCD. Indirectly, this also receives attention in the paper of Lust and colleagues (2006), who continued the study of DCD using a mental rotation task. Lust and colleagues (2006) combine an analysis of reaction time data with measurement of event-related potentials. However, unlike Williams and colleagues (2006), the children with DCD in Lust and colleagues' (2006) study did not have difficulty utilizing motor imagery. Experimental procedures such as the use of training in mental rotation before testing may explain part of the difference. Follow-up studies using larger samples may provide a good insight into the mental rotation abilities of those with DCD. It may be that a subgroup of these individuals shows an internal modelling deficit. Whatever the outcome of future studies, it is important that different researchers take up a common theme and investigate an explicit hypothesis such as this one using converging methods. Replications as well as new findings are important in a field where sample sizes are often small and individuals are known to have a heterogeneous behavioural profile.

Sensorimotor control

Sensorimotor control in DCD and related theoretical approaches are addressed by four papers in this

issue. In the first of these, Wilmut and colleagues (2006) investigate the temporal co-ordination of eye and hand movements in children with DCD when pointing to sequential targets. A specific profile of similarities and differences in the eye–hand coupling of children with DCD was found, attributed to a difficulty in linking sequential shifts of gaze and hand required for the completion of everyday tasks.

In a departure from a focus on vision–motor coupling, Whitall and colleagues (2006) investigate sensorimotor coupling between audition and motor skills. Using a clap-while-walking paradigm, Whitall and colleagues (2006) provide data to show both a developmental trajectory of skill and a difference in skill in those with DCD. The DCD group not only was less stable in coupling their movements to the auditory cue, particularly at high frequencies, but also showed impaired co-ordination of the clap and walk. With a series of interesting findings, Whitall and colleagues (2006) have provided the basis for future studies that will not only provide greater understanding of this disorder, but may also offer insights for intervention.

Inter-limb co-ordination is fundamental to many activities of daily living that children with DCD frequently find difficult – for example, running, locomotor transitions, intercepting objects while moving, and so on. Some of the basic building blocks of co-ordination have been investigated using quite simple tasks, and the study of Volman and colleagues (2006) provides a nice example of this. They investigated the co-ordination patterns of children with and without DCD when producing tapping movements with the two hands or hand and foot. An interesting pattern of similarities and differences was identified in children with DCD in comparison with their peers, showing that these children have particular difficulty co-ordinating hand–foot movements to produce stable rhythmic patterns. Such findings again provide an interesting departure for future studies to understand both the cause and consequences of DCD.

Over the years, the issue of laterality and midline crossing has been hotly debated in the field of developmental disorders. Some take the view that children with DCD are impaired when crossing the midline and having to make movements in contralateral space. A kinematic study focusing on midline crossing is reported here by Smits-Engelsman and colleagues (2006). This carefully constructed study provides a detailed investigation of children with and without DCD in both speed and accuracy when goal-directed movements are made across the midline. Contrary to expectations, this study found that children with DCD were not preferentially impaired when making movements in contralateral workspace, although they were impaired overall relative to their peers, supporting the findings of Zoia and colleagues (2005) in a reaching task performed by children with and without DCD under normal and perturbed vision. Although not tested directly, it might be that midline crossing only becomes an issue for individuals with DCD when significant postural adjustments are required, placing demands on movement planning and anticipatory control. This study provides an important methodological example of a detailed, well-controlled comparison and generates several intriguing hypotheses about the nature of movement control in DCD.

The visual control of locomotor movements has obvious implications for understanding co-ordinated action in the real world. Deconinck and colleagues (2006) present an elegant study of the contribution of vision to walking by assessing spatiotemporal gait variables when children walked in both light and dark conditions. Results suggest that a greater visual contribution to walking is evident in children with DCD compared with their typically developing peers. Once again, these findings represent an important basis for future research by suggesting a specific hypothesis to explain the disorder, in this case, the possibility of a poorly developed internal sensorimotor model.

Co-occurrence of DCD with other disorders

A number of conditions are believed to have a primary effect on movement, such as some forms of neonatal cerebral infarction (Mercuri *et al.* 2004) and prematurity with low birthweight (Hadders-Algra *et al.* 2004). Furthermore, secondary factors, such as asthma and obesity, may have an impact on movement, making it important to evaluate the

influence of such factors when assessing a child for DCD. In addition, it is now well known that motor difficulties are apparent in a number of developmental disorders, such as autism spectrum disorder (Mari *et al.* 2003), attention deficit hyperactivity disorder (Martin *et al.* 2006), dyslexia (Ramus *et al.* 2003) and specific language impairment (Hill 2001). The final three papers in this issue take different approaches to investigating this co-occurrence. In the first, Kaplan and colleagues (2006) present an opinion piece, in which they discuss their arguments for use of the terms co-occurrence and continuum (rather than co-morbidity, another term often used) and their view that the concepts of atypical brain development and minor neurological dysfunction are perhaps more useful for explaining co-occurring symptoms across developmental disorders than attempts to explain these symptoms as separate disorders. This is a hotly debated area, and has relevance when thinking about a range of neurodevelopmental disorders.

In the first of a two-pronged investigation, Scabar and colleagues (2006) evaluated the presence of DCD in a group of children diagnosed with benign epilepsy with centro-temporal spikes (BECTS). Using the Movement Assessment Battery for Children (Henderson & Sugden 1992), they found that a subgroup of these children met criteria for DCD. If these findings are replicated, this would suggest a further group of individuals who could be considered at risk for DCD. In the second part of their study, Scabar and colleagues (2006) took sleep electroencephalogram recordings of a group of eight children with DCD. This revealed the presence of rolandic spikes in more than 70% of the sample, consistent with BECTS and suggesting that those with DCD might be at risk for this condition. Again, this finding needs to be replicated but contributes to a small yet growing body of brain-based research findings.

In the final paper in this section, Green and colleagues (2006) report data from a group of children referred to a Community Paediatric Occupational Therapy service for assessment and treatment of problems with the development of motor skills. In this study, the focus of the research was on the emotional and behavioural profile, rather than on the motor skill, of the participants. This is a vital area for research given the probable influence of motor difficulties on mental health (Hellgren *et al.* 1994), participation in physical recreation, and educational achievement, not to mention the indirect (but broader) effects of these difficulties on the dynamics of family and other social systems of which the individual is part. A significant proportion of the children with DCD in Green and colleagues' (2006) study were reported by their parents to be at risk of psychopathology, stressing the importance of evaluating and supporting children' mental health and behavioural profile in addition to their motor difficulties when a diagnosis of DCD is made.

In the past 10 years, research on DCD has been reinvigorated, particularly with reference to early diagnosis and intervention. The findings presented in this special issue highlight a variety of approaches that are currently being developed. Of course, there are many important approaches and interesting findings that we were unable to include in this special issue. We must now consolidate and extend our knowledge. One way to do this will be to develop and test clear models of DCD that relate behaviour, cognition and biology. Increasingly sophisticated assessment techniques will help in this regard, as will the growing interest of the international community in this disorder and greater collaborations between research groups and between researchers, clinicians and policymakers. We look forward to further developments in this area being reported at the next international DCD conference, DCD-VII to be held in February 2007 in Melbourne, Australia, and over the coming years.

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